N O T I C E

A DESCRIPTION OF A SYSTEM OF PROGRAMS FOR MATH-
EMATICALLY PROCESSING ON UNIFIED SERIES (YeS)
COMPUTERS PHOTOGRAPHIC IMAGES OF THE EARTH TAKEN
FROM SPACECRAFT (Unit "SOFI")

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1. Report No. NASA TM-76208	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle A DESCRIPTION OF A SYSTEM OF PROGRAMS FOR MATHEMATICALLY PROCESSING ON UNIFIED SERIES (YeS)COMPUTERS PHOTOGRAPHIC IMAGES OF THE EARTH TAKEN FROM SPACECRAFT		5. Report Date JUNE 1980
		6. Performing Organization Code
7. Author(s) V. G. Zolotukhin, B. I. Kolosov, D. A. Usikov, V. I. Borisenko, S. T. Mosin, V. N. Gorokhov.		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address SCITRAN Box 5456 Santa Barbara, CA 93108		11. Contract or Grant No. NASw- 3198
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes Opisaniye Systemy Programm Matematicheskoy Obrabotki na EVM Yedinoy Serii (ES) Fotograficheskikh Izobrazheniy Zemli, Poluchennykh s Kosmicheskikh Apparatov (Kompleks "SOFI") Academy of Sciences USSR, Institute of Space Research, Moscow Report Pr- 336, 1977, pp. 1-30

16. Abstract The present paper is dedicated to a description of a batch of programs for the YeS-1040 computer combined into an automated system for processing photo (and video) images of the Earth's surface, taken from spacecraft. Since the processing system in question is the result of present and future collective efforts of many authors, it seemed to us advisable to publish sequentially the individual programs with the detailed discussion of the algorithmic and programmatic facilities needed by the user. Therefore in order to make this work possible subsequently, we at first discuss here the basic principles for assembling the system, and then we describe in detail "the control programs" and we display the "exchange format" within whose framework the cataloging of any programs recommended for the system of processing will be activated in the future.

17. Key Words (Selected by Author(s))	18. Distribution Statement Unclassified - Unlimited

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 29	22. Price

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INTRODUCTION

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The intensive development of aerospace facilities for studying the natural resources of the Earth results in the need to construct a system of data processing for the purpose of obtaining the maximum benefit. Since in the first stages of the operation basic attention was focussed on the creation of technical means for obtaining information the solution of the problem of its use has been relegated to a secondary position.

Now the situation is changing -- an ever increasing circle of users is involved in analyzing and interpreting the data. A real danger arises here: the development of similar methods and the creation of program facilities for solving the same problems due to a failure to provide for successive exchange of information and to construct processing systems on the modular principle.

With the present paper the Institute of Space Research steps forth as initiator to create a system which is convenient for the majority of users, and which has a potential for development through the contributions made by users with various interests. The basis of the system is a well-developed

* Numbers in margins indicate foreign pagination.

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exchange format of programs and data, a control program, and also a set of preliminary processing programs included in the system.

I. The functional purpose and basic tasks of the complex of programs "SOFI". With the present paper, the publication of a series of articles is initiated which are devoted to the creation of a complex of programs for an automated system of processing, on computers of the Unified Series (YeS), information received from spacecraft while studying the surface of the earth. The need to create such a complex has been repeatedly discussed by the authors in conferences attracting a wide circle of specialists occupied with questions of image processing, as well as the subsequent use of video information obtained from spacecraft. The problem cited has special urgency in connection with the great progress which has been made in the development of means for obtaining photo images of high resolution associated with the creation of the photo camera MKF-6 for the orbiting space vehicle "Soyuz-22". This space flight has made available to researchers voluminous and essentially unique material which requires operational processing on a computer and, moreover, the development of the corresponding mathematical and programmatic facilities.

As domestic and foreign experience shows [1], the absence of coordination in the development of such systems inevitably leads to explicit and implicit parallelism of operations in various laboratories and organizations. This is also fostered in no small measure by the fact that the earth's surface is diffuse in character, and the fact that it lacks a regular structure complicates the application here of the methods of mathematical modelling and often forces the researcher to resort to empirical methods. During the solution of the same problems, this gives rise to a great variety of approaches which are hard to compare. Therefore here, in or-

der to avoid the necessity for repeated programming when implementing each new type of image processing, the authors have worked out an automated system on computers specially adapted for performing certain complex operations which make it possible without any difficulty to introduce into the makeup of the system any new programs within the framework of the adopted exchange format. The basic objective of the first edition of the system considered below is, in the opinion of the authors, to present to investigators the simplest programming instrument for working with images of the earth's surface on a computer.in order to complete the scientific developments of the research plan associated with optimizing the methods for automatic classification of objects, as well as solving other practical problems. The integration of a large number of programs into the system makes it possible during operation to identify the most effective programs and to store them in the succeeding generations of a higher level system.

Let us turn to a brief analysis of the basic functional modules determining the structure and certain tasks of the complex.

At the present time in various laboratories of the Institute of Space Research of the USSR Academy of Sciences while solving certain particular problems concerning the processing of images on the computer YeS-1040 a number of programs were developed. In turn these programs served as the basic framework during the development of the complex "SOFI" with its subsequent orientation toward preliminary processing of six-zone photographs using the photo camera MKF-6. The first stage in the processing consists in the equivalent transformations of the pictures, storing the information contained in them, i.e., 1) copying the pictures on magnetic tape; 2) combining the pictures obtained in different spectral ranges;

3) correcting the linear and non-linear distortions; 4) superposing the geographical coordinate network. Then /7 color processing is carried out, i.e., the six-zonal gamma is translated into two-color, three-color, etc., images, and finally the color photograph is produced on photo film.

At this stage progress depends to a significant degree on the efficiency and quality of the technical means of visualization. At present two visualization devices are used for this purpose: a digital printing device of the computer (an alphanumeric printer (АЦПУ) and the photo output of the minicomputer "M-16". The undoubted advantage of the АЦПУ is its accessibility and the ability to use it in the burst mode of computer operation. The disadvantages are obvious, and consist, as is well-known, in a lack of clarity and a low degree of spatial resolution regarding the results of visualization. Nevertheless for a definite class of test problems, visualization by means of АЦПУ seems advisable so that the development of a universal program of visualization on a АЦПУ is included among the top-priority tasks for the compilers of processing systems.

It is well known that the most effective means of processing images on computers is the output of information for display. Since in the future it is proposed to equip the computer YeS-1040 with terminals which will include displays, the automated complex of programs under development must also include modules for visualizing on a display images undergoing processing.

Finally, a most complete and precise representation of information can be achieved by means of the photo devices of the computer "M-16". Since this computer is simultaneously capable of making designs, it in turn can be useful in certain

standard input-output procedures for inscribing drawings,
for read-outs on tape in a definite format and other service
operations. Note that here the resort to the computer 1
can be accomplished in two ways: either by equipping the
complex with special modules responsible for visualization
of information on the computer 2   , or in the case of
the use of single exchange formats this problem is solved
by a specialized program supplied on the computer 3   ,
which ensures the given deciphering and visualization of
the information previously recorded on magnetic tape in the
approved format. Since at the present time the 4
computer has no communication circuits with the YeS-1040,
the latter alternative is preferable in the opinion of the
authors.

We shall now pass on to a brief description of the modules
for the equivalent transformations of information. Among
them the most important and the most complicated is the prob-
lem of combining multizone photographs involving the super-
position of two different images of the same portion of the
surface so that all elements of the superimposed images co-
incide. The problem of superposition arises when the consti-
tuent colored images are prepared from the color-separated
images obtained simultaneously by means of cameras mounted on
a platform, as occurs with the photo camera MKF-6. In
order to facilitate the subsequent solution of this problem,
a total of 9 crosses is applied in advance to the objective
of each MKF-6 camera as coordinate reference markers. Thus
in mathematical terms the combination problem involves iden-
tifying on each photograph a preassigned triple of non-colli-
near reference crosses, and then reducing in the computer all
remaining photographs to the coordinate system of one of the
photographs, chosen as a reference, using the operations of
translation and rotation. At the present time in the Insti-
tute of Space Research in the USSR Academy of Sciences such

a program has been created and included in the composition of the complex "SOFI" [2]. After being combined, the six-zone photographs are recorded in the unified exchange format and become suitable for superposition on their coordinate network.

Here the problem is to combine the photographs with the standard portions of the Earth's surface whose coordinates in turn are well known. Thus mathematically this problem is identical with that considered above and can be solved by the same method. However, in this case the most efficient procedure may be to use the Fourier transform, making it possible to combine the photographs according to the degree of correlation of the images. At present this method is under development.

The correct solution of the problem of finding the coordinate network is also closely related to the problem of correcting linear and non-linear distortions arising on the photographs in comparison to the standard images as a result of variations in the properties of the atmosphere and other effects. Thus to make the appropriate corrections, the photographs must be subjected to special linear and non-linear transformations. For the first step of the operations the authors propose the development of a program module for linear transformations of the photographs in a computer.

The modules of the processing system described above complete the initial processing of images of the earth's surface. The subsequent processing of the images can be extremely varied and is determined basically by the practical problems of investigators in each of the interested branches of the domestic economy and the appropriate earth sciences. Next we shall dwell briefly on only those problems of subsequent processing toward whose solution some project has al-

ready been started or can be provided in a short time by
the approximate programs of the "SOFI" complex. Here the
most familiar problem is the development of a method for
automatic classification of objects when processing images. /10
The basic difficulty when introducing such a classification
is that the images under observation in each class studied
may assume an infinite variety of forms, due in part to the
variability of the earth's surface, and also to the varia-
tions in the properties of the atmosphere and in the intensity
of illumination. All this makes it extremely difficult to
define satisfactorily the representatives of the training
set which may then be used for a sufficiently reliable solu-
tion of the classification problem. One of the planned ways
to solve this problem is, as is well known, to develop an
effective system of spectrozonal signs for the reliable recog-
nition and classification of objects. This in turn gives
rise to the need to create for the computer libraries of spec-
ial characteristics of objects under study. These libraries
would be augmented and brought up to date systematically
through widening the classes of objects themselves, as well
as by extending the spectral boundaries, including the infra-
red region of radiation.

Moreover, for certain practically important applications
the simplest problem of classification may also be solved ef-
fectively by establishing the auto-correlation of various ob-
jects pictured on a photograph. Here if a photograph is iden-
tified with what is found on the earth's surface (for example,
plant cover, cultivated areas, etc.), then this information
often is sufficient for constructing a training system. At
the present time in the Institute of Space Research in the
USSR Academy of Sciences a program module has been written,
defining the degree of autocorrelation of image elements [4],
which is included in the complex "SOFI."

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Note also that the development of the automatic classi-
fication methods includes as a constituent the solution of
the problem of isolating or accentuating contours delimiting
various homogeneous regions or encompassing nominally homogen-
eous regions of natural formations within the limits of ad-
missible precision for describing them by the accepted class-
ification of objects. In the Institute of Space Research
in the USSR Academy of Sciences, on the basis of gradient
approaches and regression analsyis, a program has been writ-
ten for isoluting contours [3], which is also included in the
system of image processing.

Next, the authors consider it necessary to introduce
into the makeup of the complex "SOFI" a program for deter-
mining the parameters of theoretical models through the re-
sults of measurements [5]. The program in question has shown
a high degree of effectiveness in different physical applica-
tions and can be useful in the conduct of many researches,
in particular, when classifying objects to be identified
in the non-linear space copying their signs.

At the present time in the Institute of Space Research
in the USSR Academy of Sciences effective programs of one-and /11
two-dimensional Fourier transforms (БПФ) have been developed.
As noted above, the БПФ can be a reliable means of solving
a number of problems involving the processing of images. In
particular the БПФ can be used successfully to synthesize
complex optical filters on computers modelling holographic
methods for processing images. Thus equipping the complex
"SOFI" with БПФ programs, followed by the development of spe-
cial progrь modules for the algebra of rapid Fourier trans-
forms will provide a reliable program base for creating new,
effective methods for processing images on computers.

Finally, to conclude the present section, let us note
that combining programs for prccessing images within the frame-

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work of the single automated system "SOFI" solves a whole series of problems, the most important of which are the <u>/12</u> following.

1. Subsequent work to extend the mathematical and program facilities applicable to the study of the earth's natural resources can be efficiently planned.

2. Duplication in the creation of programs and algorithms is eliminated.

3. The input and output information recorded on computer media is unified, and this in turn facilitates the exchange of data between various organizations.

4. Natural conditions for a comparative analysis of the effectiveness of different approaches are created as the result of solving the problems of processing images on a computer.

5. Setting up the program complex "SOFI" on the YeS-1040 computer facilitates the exchange of programs between different groups of developers.

II. <u>Organization of the complex</u>   <u>/13</u>

1. <u>Interaction of the modules of the complex</u>

<u>Control program</u>

The structure of the complex is modular. Each module is a set of programs located in the absolte module library of the system **ДOC.EC.** [DOS YeS]. Each module solves a particular problem; for example, translation of incoming information from one format into another, visualization of images, gradient transformation, etc. In case of a concrete calculation,

the order of call of modules must be defined. The given
order of processing the modules is provided by the control
program of the complex.

Each module of the complex is cataloged under a definite
number which must not exceed 9,999,999. Usually a programmer
working on a supplement to "SOFI" receives an interval of
numbers for cataloging his programs.

A calculation via the complex is always initiated by
calling the module "job loader." For this purpose, a job
management command is used: // EXEC V00000000

The module "job loader" reads information from a punched
card input device. This information determines the order in
which modules are processed, and also controls the work of
each module. The punched cards (pk) are made up as follows:

1 pk. -- the number of the first module called (format I7)
2 pk. -- the control for operating the first module called
          (format 32 II)
3 pk. -- the number of the second module called (format I 7)
4 pk. -- the control for operating the second called module
          (format 32 II). etc. but in a job there can be de-
          fined a list of at most 20 modules.

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/* - the sign of the end of the information defining the order
of operation of the modules.

The structure and dedication of the punched cards con-
trolling the operation of the modules is explained below.
The loader module is numbered 0 in the library of absolute
modules in the complex. The module is written in FORTRAN IV.
This listing is given in Appendix I.

The module "job loader," which introduces the informa-

tion for operating the modules, prints the formulated job, for example:

[OPERATES THE COMPLEX FOR PROCESSING VIDEOIMAGES VIDEO
    *   ]
[CONTROL FOR OPERATING THE COMPLEX]
[ORDER]   [NUMBER OF MODULE]   [CONTROL]

1	3000003	001111100000011000000000000000000
2	2002	000101011100011000000000000000000
3	3000003	111011010101000000000000000000000

and calls the control module of the complex. The control module of the complex calls the first module shown in the list and feeds into its control file:

[MODULE CALLED]   2002

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0	0	0	1	0	1	0	1	1	1	0	0	0	1	1	0	0	0	0	0

21	22	23	24	25	26	27	28	29	30	31	32
0	0	0	0	0	0	0	0	0	0	0	0

Each module whose work has been completed normally, again calls the control module:

[MODULE FINISHED]   2002   [MESSAGE ARRIVED]
[MODULE CALLED]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1	1	0	1	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0

21	22	23	24	25	26	27	28	29	30	31	32
0	0	0	0	0	0	0	0	0	0	0	0

*Illegible in foreign text.

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The control module calls the next module (in accordance with the list of jobs) and feeds into it the control file, etc., and reports

[MODULE FINISHED]   [MESSAGE ARRIVED]

[CALCULATION VIA COMPLEX ENDED]

and the calculation by means of the complex is terminated.

The file of controls for operating a current module is transmitted by the control module via the unlabelled COMMON block. The control file is the complete file IABC(32) in each four byte element of which the number 0 or 1 is contained, depending on whether 0 or 1 was printed on a punched card in the corresponding digit for controlling the work of the given module (Recall that the format of the record on a control punched card is 32 I I). The presence or absence of a unit in a particular element i of the control file $IABC(i)$ serves as an indication by means of which the programmer can supervise the order of processing blocks in the module. For example, suppose the fifth element controls the print mode. Then the print operators will have the form

    if(IABC(5). EQ. 1) WRITE(3,   )

print will be carried out if IABC(5) equals 1.

The number of the control module in the library of absolute modules in the complex is I .

The module is written in FORTRAN IV.

The listing is given in Appendix 2.

2. Storage and transmission of control files.

During a calculation by means of the complex the files controlling the operation of the complex are stored in the main storage. This is achieved because all the main programs of the modules are obliged to have an unlabelled COMMON block. Clearly this block must have all the subprograms of the module which pertain to the unlabelled COMMON block. The COMMON block must have one of the following three forms:

Complete description

```
DIMENSION INTEGER*2 PRIK(20,32)
COMMON IABC(32),IS,K,IZAD(20),PRIK,ISOOB(20)
```

and further, if necessary, the module's own file.

Incomplete description

```
COMMON IABC(32),IS,FICT(361)
```

and further, if necessary, the module's own file.

"Blind" description

```
COMMON FICT(394)
```

and further, if necessary, the module's own file.

The files in a complete description have the following content

IABC(32) -- the control file

IS -- the identifier of a message in a module any number may be assigned to this identifier. After returning to the control module this number is printed. Moreover, it will be placed in the file **IS OOB** (   ) at the Kth place. If in

a given module no value is assigned to **IS** then the control
module prints that the message 0 has arrived.

Messages can be used for information about any results in
the module. And since they are placed in the file **IS OOB**
and stored, they may also be used as information transmitted
from module to module. It should be noted that this capability
of the complex is rarely used by programmers. K is the ordinal
number of the given module in the list of jobs for calling
modules.

IZAD (20) — is the file in which the list of modules
is stored which the control module must
call.

PPIK (20,32) — is a file of the type $integer \times 2$; in
it is stored the file of controls for the
operation of the modules.

IS OOB (20) — is the file in which messages of the modules
are stored.

Usually the incomplete description of the COMMON block
is used which makes it possible to obtain the control IABC
and to transmit the message **IS** .

3. <u>The subprogram for calling modules</u>   /18

To call modules of the complex, a special subprogram is
used. It is stored in the library of object modules of the
complex and can be called as a subprogram.

CALL NEXTV(N)

N — is an integer variable or integer.

The control module of the complex is called by the opera-
tor **CALL NEXTV(1)** . The subprogram NEXTV can call any
module of the complex without reference to the control program.

From the viewpoint of the control module, the entire super-module has the number of the first module called from the super-module. The subprogram **NEXTV** is stored in the library of object modules of the complex. The subprogram is written in the ASSEMBLER language. The listing is given in Appendix 3.

4. Cataloging absolute modules

The basic structural unit of the complex is the module located in the library of absolute modules. The job for cataloging a module in the library of absolute modules is organized as follows:

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```
//  JOB     NAME
// ASSGN SYSCLB,X'190'DISK 102
// ASSGN SYSRLB,X'190'DISK 102
```

(According to this command the operator places disk No. 102 with the complex and assigns to it the cataloging of the absolute and object modules. The number of the disk may differ from that shown in the present example).

```
// OPTION CATAL
   ACTION RL
   PHASE V N1N2N3N4N5N6N7,*
```

$PHASE\ V\ N_1 N_2 N_3 N_4 N_5 N_6 N_7,*$

($N_1 N_2 N_3 N_4 N_5 N_6 N_7$ is the number of the module; for example 0011000 or 0000005, etc.).

The usual job for translation is, for example:

```
// EXEC FFORTRAN
```

```
    text of basic program
    text of subprogram
```

```
/*
// EXEC LNKEDT
```

5. Cataloging object modules

As a result of the transformation of the system *DOS EC
V.M 2.0* , cataloging object modules has been complicated.
The job for cataloging a subprogram in the library of object
modules is organized as follows:

```
// JOB
// PAUSE ASSGN SYSPCH,X'190'[DISK]102
// PAUSE ASSGN SYSRLB,X'190'[DISK]102
// OPTION DECK
// EXEC HELPCAT
 CATALR [NAME]
// EXEC ASSEMBLP  [OR]  // EXEC PFORTRAN
        [PROGRAM]
/*
...
CLOSE SYSPCH,X'OOD'
// PAUSE ASSGN SYSIPT,X'190'
// EXEC MAINT
CLOSE SYSIPT,UA
// PAUSE [RECLAIM ASSIGNMENT FOR]    SYSIPT
// OPTION NODECK
// EXEC DSERV
 DSPLY ALL
```

Note: the number of the library disk can be changed.

6. Information about the makeup of the complex.

For successful functioning of the complex, in whose syn-
thesis a large number of programmers has participated, it is
necessary to provide operational access to information about
augmentations and changes in the complex. To this end, each
module included in the complex is equipped with a description.

The number of the description of a module is one million greater than the number of the corresponding operating module. For example, if the operating module has the number 321, then the module in which the description of the module 321 is contained has the number 1000000 + 321 = 1000321.   /21

Only when a module has been provided with a description is it considered to be included in the library of absolute modules of the complex.

$$1.000000 + 321 = 1000321.$$

The description of an absolute module can be called by the command

$$// \text{ EXEC } V \text{ } N_2 - N_7$$

or through the complex, after the call of the corresponding module in the list of jobs for the calculation

$$1N_2 N_3 N_4 N_5 N_6 N_7/$$

is placed, where $N_2 N_3 N_4 N_5 N_6 N_7$ - is the number of the operating module, e.g., 000321.

The description of an object module is placed in the library of absolute modules under the assignment $V1 A_1 A_2 A_3 A_4 A_5 A_6$ where $A_1 A_2 A_3 A_4 A_5 A_6$ consists of the first six symbols in the assignment of the object module under which it is called in the programs. For example, to the subprogram NEXTV corresponds the assignment V1NEXTV in the description placed in the library of absolute modules. The module of the description of an object module can be called from the library of absolute modules only by the command EXEC .

For example:

$$// \text{ EXEC } V1NEXTV$$

The description of a module or subprogram must contain

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the following divisions:

1. The assignment of the module.

2. The decoding of the controls of the module.

3. The format and the means of input of external data for
    a calculation by means of the module.

4. The format and the means of output of the results of a
    calculation by means of the module.

An example of a description is given in [6].

III. Exchange format /22

Video information subject to processing on a YeS computer
is usually made ready on a standard medium--a magnetic tape,
accepting up to 10^8 bytes of information placed on one reel.
To make possible a broad exchange of original material as well
as the results of processing, there must be a uniform standard
for the format of placement of information on magnetic tape.

The different sources of video information (scanners,
multispectral photo recorders, etc.) determine their intrinsic
natural form of placement of data. The specifics of scanner
information are such that the intensities of reflected light
in various spectral channels corresponding to an element of
resolution on the earth's surface succeed each other and during
transcription from specialized to standard magnetic tape,
blocks of n groups of K bytes (of color vectors) each are
formed [4] (K is the number of spectral channels in which
recording occurs and n is the number of elements per image
line). This organization of video information is natural for
scanner information.

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The materials from multispectral photo cameras arrives in the form of negative or positive color or black and white images. The input of information is accomplished separately in each spectral region of the entire material. To receive information on magnetic tape in a form like that received during transcription of scanner images, it is necessary to perform a quite large operation involving the combining of color-separated information. The difficulties arising during combination can be overcome and the information can be presented in just such a standard.

The programs of visualization and/or statistical processing which have been developed may be necessary not only for original information, but also for any processed information (e.g., differentiated or filtered). Consequently it is desirable to represent the results of processing in such a form that no problem of describing new programs, e. g., of visualization, arises. In the majority of cases this is possible.

. The number of reels of magnetic tape with video information is quite large, even when processing the results of a modelling experiment. To make it possible to identify the contents and to avoid operator errors, in the ДOC system [Disk Operating System] a method has been worked out whereby special header and tail labels are placed at the beginning and end of each reel [7]. The presence of standard labels makes it possible to process data on magnetic tape by means of programs written in different programming languages, FORTRAN, ASSEMBLER, etc.

Two basic formats for original information are possible: scanner and spectrally divided.

In the scanner format a line consists of n color vectors of K components and contains service and auxiliary information,

recorded at the time of the reverse travel of the scanning
device which is not strictly video information. At the present
time this auxiliary information is not used as a rule; however,
in the future many of its parameters, such as, for example,
the magnitude of the noise, the amplification factor, the time,
the direction of flight, etc., may provide substantial help
in deciphering images. The physical unit of a record of
scanner information is a line of an image or its part. The
arrangement of the material in a line has the following form:

$$\boxed{N}\ \boxed{b_1}\ \boxed{b_2}\ \cdots\ \boxed{b_n}\ \boxed{C.\text{M}.}$$
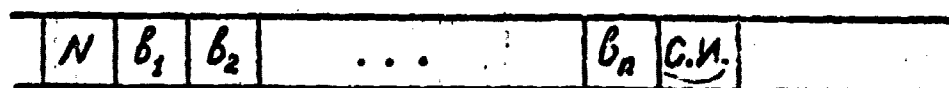
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here N is the number of lines during repackaging of information
and is either the ordinal number of the line, or is obtained
from the number of the line, determined at the moment of photo-
graphy and recorded instrumentally at the time of reverse
travel. N is placed in the first four bytes of the record.
$b_1, b_2, \ldots b_n$ are the color vectors, each of which occupies
K bytes, where K is the number of spectral ranges. $C.M.$
is the service information recorded instrumentally on tele-
metric tape.

The existing scanner provides 2048 bytes per line, of
which only 1536 represent video information. The scanning
devices which have been developed can have lines of length 4096,
8192 and more bytes each. In this case it is proposed that
properly speaking a line of an image breaks down into blocks
of 2048 or 4096 bytes each, and the presence in two or more
lines of the same number in a line is evidence that blocks
with the same numbers correspond to a single line and are
distributed on an image from left to right one after the other.

During recording, blocks are separated from each other
by interblock intervals. The set of information blocks forms
a file with standard header and tail labels. The first block

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after the header labels of the file **VOL1** and **HDR1** [7]
can be an information block of length 512 bytes. This block
contains information about the organization of the material
and parameters of the recording apparatus; test characterist-
ics, commenting data, the number of spectral ranges, wave-
lengths, etc. The presence of such a standard block makes
it possible to construct programs adjusted to a given con-
crete organization of data and to have verbal commentaries
about the material on a given reel.

The arrangement of information in an informational line
is

The line contains 512 bytes. The words of the recording $\quad$ /25
$\beta_1, \beta_2 \ldots \beta_9, \Pi_1, \Pi_2 \ldots$ contain 4 bytes each; the words $t_1 \ldots t_p$
64 bytes each; β_1 is the number 0. β_2 is the type of
recording. If $\beta_2 = 0$, the information in a line of the
image is recorded in a sequence $\Pi_1, \Pi_2 \ldots \Pi_K$, i.e., for
an element of the image, all K spectral intensities are
recorded; then we have $\Pi_1, \Pi_2 \ldots \Pi_K$ for a second element
of the image, etc.

If $\beta_2 = I$, the information in a line of the image
is recorded in a sequence $\Pi_1', \Pi_1^2 \ldots \Pi_1^n \Pi_2' \Pi_2^2 \ldots \Pi_2^n$, i.e.,
at the beginning for the entire line of the image is the
spectral intensity of the first channel, then for the same
line, the spectral intensity of the second spectral channel,
etc.

β_3 - is the length of the physical recording

β_4 - is the number of elements in a line of the image
(for a single spectral channel).

β_5 - is the number of spectral channels.

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β_6 · is the approximate number of lines in the image

β_7 · is the aperture

β_8 · is the raster
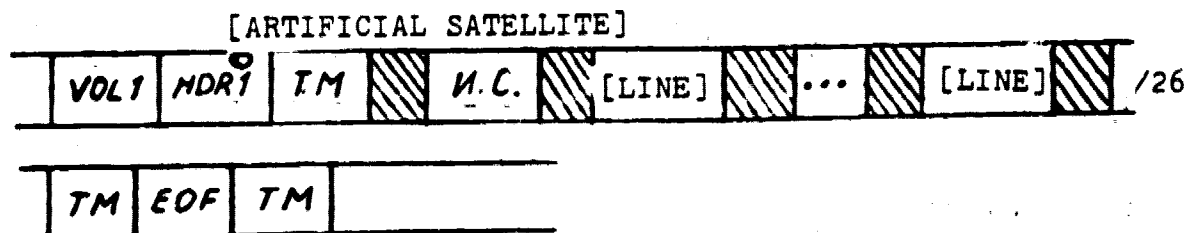
β_9 is the scale

λ_1 is the wave length of the first spectral channel

λ_2 is the wave length of the second spectral channel

λ_k is the wave length of the K th spectral channel.

In the words $t_1, t_2, \ldots t_j$ any alphanumeric information about the photograph is recorded.

Thus the format of scanner video information has the form:

[ARTIFICIAL SATELLITE]

| VOL1 | HDR1 | TM | //// | M.C. | //// | [LINE] | //// | ... | //// | [LINE] | //// | /26 |

| TM | EOF | TM |

The spectral format is naturally obtained during the introduction of the negatives from various spectral ranges. In this case (after carrying out geometrical correction and combination) the lines of the image consist of K blocks, each corresponding to a separate spectral range. Since the length of a line (the number of elements in the line) is determined not only by the dimensions of the negative, but also by the aperture of the reader, and also by the desire of the user to study an individual fragment of the image, it seems reasonable not to fix the length of a line rigidly.

It is desirable to have the length a multiple of 2048 bytes, placing in one block or several spectral ranges, corresponding to one line (when there are small fragments), or placing in several standing blocks in succession, data characterizing a single line in the corresponding spectral ranges: in such a case the presence of an informational line is necessary in order to work with such material.

VOL1	HDR1	TM	И.C.	[BLOCK]	GAP	[BLOCK]

[SPECTRUM] N 1	[SPECTRUM] N 2	[SPECTRUM] N K	[SPECTRUM] N₁ 1	...	[BLANK]
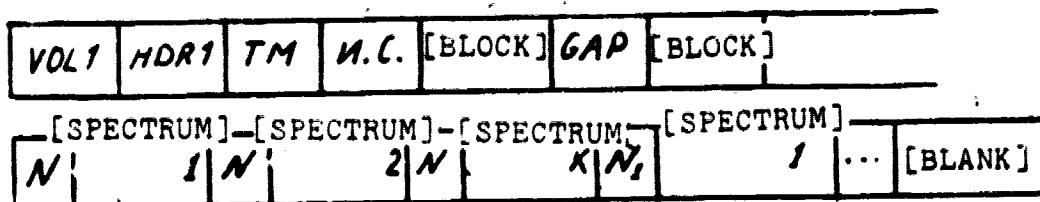
The block for a small fragment (several lines in one block).

N	[SPECTRUM] 1	[BLANK]

N	[SPECTRUM] 2	[BLANK]

a group of blocks for a large fragment -- one line per several blocks.

It is obvious that it is also possible to represent scanner information in a spectrally separated format. When developing programs it is necessary either to prepare self-adjusting programs relative to the $N.C.$, or to provide for the possibility of an easy program change for their work with data in various formats.

In conclusion the authors consider it their duty to mention the participation of Comrade L. S. Chesalin touching on the questions in this article.

Appendix 1. Job loader module.

```
      DIMENSION IZAD(20),ISOOR(20)
      INTEGER*2 PRIK(20,32)
      COMMON IABC(32),IS,K,IZAD,PRIK,ISOOB
      WRITE(3,101)
      I=1
2     READ(1,200,END=10)IZ
      READ(1,100) (PRIK(I,J),J=1,32)
      ISOOB(I)=0
      WRITE(3,102) I,IZ,(PRIK(I,J),J=1,32)
      IZAD(I)=IZ
      I=I+1
      GO TO 2
10    IZAD(I)=0
      WRITE(3,107)
      K=0
      CALL NEXTV(1)
100   FORMAT(32I1)
101   FORMAT(//45X,['operates complex for processing video images']
     *['video-77']/
     *['controls for operating the complex']
     *['UTEREAD'];['order,' 'module number,' 'control']
     *27X,32(1H ))
102   FORMAT(1X,I5,7X,I7,7X,32I1)
200   FORMAT(I7)
107   FORMAT(/1X)
      END
```


Appendix 2.   Control program for the complex

```
103   FORMAT(//' ['operation of module concluded,'] [message arrived.']
104   FORMAT(1X,'['module called']',I8)
105   FORMAT(/1X,32I3/' ')
106   FORMAT(1X,'['calculation by means of module ended']
      DIMENSION IZAD(20),ISOOB(20),IABC(32),L(32)
      INTEGER*2 PRIK(20,32)
      COMMON IABC,IS,K,IZAD,PRIK,ISOOB
      IF(K) 9,8,9
9     NMOD=IZAD(K)
      WRITE(3,103) NM-D,IS
      ISCOR(K)=IS
8     K=K+1
6     NMOD=IZAD(K)
      IF(NMOD)4,4,3
3     DO 5 J=1,32
5     IABC(J)=PRIK(K,J)
      WRITE(3,104) NM-D
      DO 7 I=1,32
7     L(I)=I
      WRITE(3,105) (L(I),I=1,32)
      WRITE(3,105) (IABC(I),I=1,32)
      IS=0
      CALL NEXTV(NMOD)
4     WRITE(3,106)
      STOP
      END
```

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Appendix 3. Subprogram for calling modules from the library
of absolute modules.

```
 1              PUNCH ' CATALR NEXTV'
 2    NEXTV     START
 3             RALR    3,0
 4             USING   0,3
 5             L       4,0(1)
 6             L       4,0(4)
 7             LVO     4,0
 8             UNPK    N,D
 9             OI      N+6,X'FO'
10             LA      5,A
11             FETCH   (5)
12++  DOS/ES   FETCH   V.M,2.0
13+            DC      OM'O'
14+            LR      1,5
15+            LR      0,0
16+            LVC     1
17  D          NS      D
18  A          OC      CL1,'V'
19  N          NS      CL7
20             END     A
```

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